The Effects of Small-group Cooperative Learning Strategy on College Students' Performance of Basic Mathematics

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Abstract: This article reports the contribution of small-group cooperative instructional strategy among pre-service teacher education students in learning college level discrete mathematics (Math 122). Two classes of second-year students from one Ethiopian teacher education college participated in the study. The classes were arbitrarily assigned into Treatment and Comparison group. The Treatment Class was taught using small-group cooperative learning strategy, while the Comparison Class was taught using the traditional teacher-dominated strategies. Data sources of the study were scores of: Group Performance Rating Checklist (GPRC), Procedural-Conceptual Mathematics Test (PCMT), Math 122 Test, and Year I Cumulative Grade Point Average (CGPA). The PCMT was the sum of Procedural and Conceptual mathematics tests. Analyses of GPRC data showed that students in the Treatment Class made significant shifts towards displaying learning behaviors that enhance learning in small-group cooperative instructional settings. Despite the fact that the analysis of CGPA showed comparable prior academic performance of both classes ($t = 0.75$, $p \geq 0.01$), the Treatment Classes significantly outperformed their counterparts in mean Conceptual Mathematics test ($t = 3.73$, $p \leq 0.01$), Total PCMT ($t = 2.88$, $p \leq 0.01$), and Math 122 test scores ($t = 3.86$, $p \leq 0.01$). In conclusion, small-group cooperative learning strategy improved students': (a) involvement in mathematics learning, (b) ability in solving conceptual mathematics problems, and (c) performance in mathematics tests. Implications for classroom practice and further research are provided.

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Introduction

Cooperative learning is one of the instructional strategies that satisfy the social constructivist view of mathematics instruction. Cooperative learning emanates from the social nature of learning (Bell, 1993; Cobb, et al., 1991; Good, et al., 1992). Educators agree that meaningful learning is maximized when there is cooperation in the learning process (e.g. Fitzgerald and Bouck, 1993). Cooperative learning promotes understanding and justification in problem-solving and gives little space for competition and individual instruction (McGlinn, 1991). However, it should be noted that cooperative learning is not simply putting a small number of students into groups and let them do something, as is usually the case. The principles underlying cooperative learning and cooperative learning groups are broad. In designing a lesson using cooperative learning strategy, teachers have to ensure that: (a) groups are small, (b) students mutually and positively depend on one another and on the group's work as a whole, (c) learning environments offer all members of a group equal opportunity to interact with one another, and (d) members of a group feel responsible to contribute to group activities and are accountable the learning progress of the group (Good, 1992; Leikin and Zaslavsky, 1999 quoted in Jardine and McDuffie, 2001).

Cooperative learning strategies help attain maximum student learning through sharing, interacting, negotiation of meanings, and understanding (Huetinck and Munshin, 2000). Below average and average achieving students benefit from the expertise of their competent peers and the teacher. As competent students guide their low achieving peers, they remain persistent in their competency or improve it (Koehler and Prior, 1993). Also, cooperative learning strategies enhance student interest to learn mathematics. They encourage students to work together to solve problems. Cooperative learning groups improve their learning by talking to each other in their own terms about how they arrive at a particular solution. Group members improve their abilities in assessing peers' works. Cooperative learning challenges low-ability students to work harder while benefiting other groups. Furthermore, cooperative learning strategies help teachers assess students' abilities and understandings easily and tangibly (Huetinck and Munshin, 2000; Posamentier and Stepelman, 1996).

Three categories of cooperative learning are available (MoE, 2006), namely: (a) formal, (b) informal, and (c) base cooperative learning. Formal cooperative learning is used to teach specific contents and problem-solving skills. Activities may last for several weeks, where students take roles and responsibilities for the success of the group. Assistance comes from teachers and competent peers. Informal cooperative learning is frequently used to ensure cognitive processing during a lecture, lasting for a part of or full session. Lastly, base cooperative learning is employed to provide long term support for academic progress. It requires a long time to promote positive interdependence both inside and outside class.

Nevertheless, quite limited research is available globally on the benefits of cooperative learning strategies among secondary and college level students. Studies aiming at enhancing mathematics learning and teaching are non-existent in Ethiopia. The present study explored into the effect of cooperative learning strategies on student involvement in learning mathematics, conceptual problem solving abilities, and performance among Ethiopian second year pre-service teacher education college students. For this purpose the following questions were addressed.

(a) Does cooperative learning strategy improve student involvement in learning mathematics?
(b) Does cooperative learning strategy enhance student ability to solve conceptual mathematics problems?

(c) Does cooperative learning strategy improve student performance in mathematics?

Definition of Concepts

Small group: A group which may include 2-5 individuals during learning activities with a shared aim and combined effort to attain their set goal. It is established with the aim to develop students' social and language skills and as a means by which students support, challenge and extend their learning together.

Cooperative learning: is a form of small-group instruction. It complements direct instruction. Competitive learning is a way of learning that provides teachers with opportunities to observe students' learning more closely and, through questioning or providing information, or supporting provision, it helps students advance to new knowledge, skills, or understanding.

Traditional Teacher-Dominated strategy: it refers to the teaching practice where the teacher makes much use of teacher-centered, exposition-dominated activities. It involves teacher-directed seatwork tasks. Traditional teacher dominated strategy there is a great deal of guided practice. In which the students face the teacher and the blackboard.

Mathematics Performance: refers to the marks a student scores in mathematics tests after the delivery of the intervention program.

Review of Literature

Cooperative learning establishes a systematic relationship among students in learning (Huetinck and Munshin, 2000). However, simple collections of individuals do not yield effective cooperative learning settings (Posamentier and Stepelman, 1996). Teachers have to use ingenious strategies to come up with successful cooperative learning models. In a typical problem-based teaching-learning of mathematics cooperative learning facilitates mastering of academic content and promotes higher-order thinking. It provides students with the opportunity to think logically and creatively. It also fosters student achievement and enhances ability in problem solving, and improves student strategies of acquiring information. Furthermore, cooperative learning models develop personal and social skills, boost student self-esteem, and improve students' abilities to learn with others. The strategies also help students develop self-reliance and self-confidence. The strategy motivate students to learn and encourage interaction and communication to take place among them cooperative learning strategy enhances possible gender relations, and allow students to make decisions in learning (Hopkins, 2002; Marsh, 2004; McGlinn, 1991; Thornton and Wilson, 1993).

It is well established that active learning strategies increase student motivation to learn. Such strategies provide students with the opportunity to see and learn alternative problem solving methods. Small-group cooperative learning strategies promote active student learning. In fact, the benefits of small-group cooperative learning strategies are extensively discussed in the literature (e.g. Felder and Brent, 2002; Hopkins, 2002; Huetinck and Munshin, 2000; Marsh, 2004; Renga and Dalla, 1993). Under individual learning settings students may get stuck when confronted with perplexing or challenging problems. In cooperative learning settings, on the other hand, students in groups keep working with initiation. Students learn with understanding when they teach their peers or learn from their peers (Cathcart, et al., 2001). In small-group cooperative learning settings representing, talking, listening, writing, and reading are used at a full scale. "…small-group is a forum in which students ask questions, discuss ideas, make mistakes, learn to listen to others ideas' offer constructive criticism, and summarize their discoveries in writing" (National Council of Teachers of Mathematics [NCTM], 1989, p. 79). The benefits of cooperative learning models to students and teachers are provided in the works of Huetinck and Munshin (2000).

Models in Cooperative Learning Lessons

Huetinck and Munshin (2000) designed four models of cooperative learning lessons, namely: (a) think–pair–share, (b) team learning, (c) random selection, and (d) collaborative learning. Think–pair–share is employed in solving non-routine and open-ended problems. In this case, students are provided with the opportunity to apply mathematical reasoning and varied tools to tackle problems by means of several one-on-one interactions within a group. This model ensures high involvement and participation of every member of a group. Team learning – of three to five students – involves group self-assessment after members completed the different tasks or roles that they took. On the other hand, random selection model is designed to promote mastery of specific skills. In this case, a group of four students work cooperatively to work on exercises, anticipating that any member can be called up on by the teacher to explain the answer of the task. Lastly, collaborative learning is designed to allow students to work in small-groups on a common task. Students correct homework at the beginning of a class so that they have the opportunity to get help from group members. Nonetheless, teachers have to be aware of the need to include other activities to overcome the drawbacks of collaborative learning. The draw backs are that cooperative learning decreases individual accountability. It may not ensure student understanding. It also teachers have to be aware of the need to include provides less room for reflection.

There are two basic approaches to forming cooperative learning groups, namely "structured" and "random selection" approaches. In the first approach, a heterogeneous group of four students – one high achieving, two average achieving, and one low achieving – are set up by the teacher prior to instruction. In each instructional session, group members are assigned distinctly new roles in such a way that high achieving students are not dominating. In the second approach, cooperative learning groups are set up without any criteria. The risk of having overabundance of high achieving, average achieving, or low achieving students is apparent. Several workers have reported about the effectiveness of heterogeneous cooperative learning grouping (e.g. Slavin, 1987; Lincheviski and Kutscher, 1998; Artzt, 1999).

Tips for Successful Cooperative Learning

Whereas, there are several strategies of planning cooperative instructional models, the best models consider: (a) positive interdependence – where group members feel responsible for the achievement of a common goal and success, (b) individual accountability – where every group member takes responsibility for learning, (c) face-to-face interaction – where group members are brought to close proximity to ensure dialogue and learning, (d) social skills – where group members function effectively through communication, leadership, conflict management, etc., (e) processing – where group works are assessed for improvement, and (f) heterogeneous groups – where group members are diverse in gender, social background, skills, and physical attributes (Fitzgerald and Bouck, 1993; Good, et al, 1992; Hopkins, 2002; Thornton and Wilson, 1993). Moreover, cooperative learning strategies become more effective when students develop desirable group behavior; teachers employ group interaction methods that enhance active learning; and group contracts are set to avoid conflicts (MoE, 2006; Hillier, 2002; Hopkins, 2002; Rhodes, et al., 2004). Thus, the success and efficiency of small-group cooperative learning models depend on members': agreement on a common goal; commitment to be accountable and responsible for the success of the group; readiness to talk, discuss, and negotiate ideas; and willingness to take roles in group activity to ensure the success of common goal (Posamentier and Stepelman, 1996). Likewise, lists of other tips exist in the literature (e.g. Basic Education Support in Tigrai [BEST], 2002; MoE, 2006; Huetinck and Munshin, 2000).

The context in which cooperative learning activities are planned, i.e. the nature of the activities is equally important in affecting the success of mathematics instruction. Activities that require listening, taking notes, working on exercises, and writing explanations about mathematical processes are suitable for individual learning. On the other hand, activities that: (a) are completed in several stages (b) require multiple solution courses, and/or (c) sufficiently complex that elicit strong student discussions are appropriate for group cooperative learning (Huetinck and Munshin, 2000).

Methodology

Subjects

Eighty second year pre-service teacher education college students, enrolled at Mekelle College of Teacher Education in 2007/8 academic year participated in the study. The students were assigned into two classes of 40 students each by the college registrar. The classes were arbitrarily assigned into Treatment and Comparison classes. Two students from the Comparison Class did not complete the intervention. While the teacher who was assigned to the control/comparison group used the traditional teaching material, the teacher (the first author) assigned to the treatment class used the same content with the traditional teaching material but with modifications to meet the requirements of cooperative learning.

Ethical Measures: Specific ethical measures were introduced in order to respect the integrity and humanity of the participants. To do this effectively, the guidelines for informed consent, the *Institutional Guide to DHEW Policy*, (1971) was strictly adhered to. The research group made a fair explanation of: the procedures to be followed and the purposes of the research project, the risks and benefits expected and the alternative procedures that might be advantageous to the participants in the project. In addition to this, the group assured to offer an answer to any inquires concerning the procedure. Instruction that a participant is free to withdraw and even to change to the other group in case he or she feels discomfort with the new approach was also given. They were informed that they would be graded independently to avoid discrepancy as a result of the two teaching approaches.

In line with the guarantee that the participants offered as a result of informed consent, we made keep on to aware the participants aware about current government policy documents that persistently support the small group cooperative learning. For instance, the Teacher Education System Overhaul (TESO) (MoE, 2003) and the School Improvement Program (SIP) (MoE, 2007) are among others steps that helped us convince students in the experimental group to volunteer to be part of the program.

The Intervention

Once the Treatment and Comparison classes were identified, students in the Treatment Class were trained in small-group cooperative learning strategies during their enrolment for second year college mathematics course called Basic Mathematics II (Math 122). Then, while the Treatment Class was taught the course by the first author based on the theory, principles, and practices of cooperative learning groups, the Comparison Class was taught by a teacher educator who is less-acquainted with cooperative learning models. In the Treatment Class, heterogeneous cooperative learning groups were set up using structured approach. Instructional activities for the experimental were based on the theories, principles, and practices of cooperative learning. On the other hand, the Comparison Class adapted a typical traditional teacher-dominated instructional approach, where few proactive students dominated the classroom discourse. The intervention was conducted run from the first week of October 2007 to the second week of February 2008.

Classroom Organization: Defining the Context

The instructional activities in the experimental class lent themselves to two types of classroom organizations. In the first place, students generally worked in small groups to solve the instructional activities, reflect on and negotiate ideas. They were encouraged to use a variety of solution strategies they found most appropriate. The teacher observed and interacted with the students as they were engaged in mathematical activity in small groups. After the students worked together for 15-20 minutes, the teacher facilitated and encouraged a whole-class discussion of the students' analysis and solutions.

In contrast with the (researcher) who taught the treatment class, the teacher who taught the comparison class encouraged teacher dominated mathematics lessons. Individual paper- and –pencil seatwork dominated the activities of the control group.

In the second place, instructional activities were used solely in a whole-class setting in the treatment class. The teacher naturally initiated these activities by posing questions from student presentations of their group work. The teacher in the treatment class facilitated classroom discourses and communication in which explanations, meaning formation and solutions were appreciated.

Unlike the teacher who was assigned to the comparison, the teacher in the treatment class facilitated students' construction of mathematical knowledge. He initiated and guided the negotiation of classroom social norms. This influenced students' motivation and beliefs about their role, the teacher's role, and the nature of mathematics.

As part of his role, the teacher in the treatment class encouraged students to believe that success in mathematics depends on individual and collaborative attempts to understand things in ways that make sense to them.

Instruments of Data Collection and Analyses

In this research project, four data sources were used, namely: (a) Year I College Cumulative Grade Point Average (CGPA), (b) Group Performance Rating Checklist (GPRC), (c) Procedural-Conceptual Mathematics Test (PCMT), and (d) Math 122 test scores.

Year I college Cumulative Grade Point Average (CGPA). In the first place, Year I college CGPA was used to compare the prior academic performance of the two classes. Mean scores of the Treatment and Comparison classes were compared using independent sample t-test. This helped us to assess if the two groups of students are comparable from the outset.

It is believed that the validity of quantitative data is improved through careful sampling, appropriate instrumentation and appropriate statistical treatment of the data.

Group Performance Rating Checklist (GPRC). The GPRC was adapted with modification from the works of Huetinck and Munshin (2000), van de Walle (1998), and Johnson (2002). It was designed to measure students' participation in mathematics learning and the quality of participation in cooperative learning. The Checklist contains six major categories of student learning behavior, namely: '*group participation'*, '*staying on topic/on-task*', '*offering useful ideas/supporting'*, '*consideration*', '*involving others'*, and '*communicating. E*ach of the category contained three to four statements. Thus, the Checklist included 22 items to which students responded using a four-point rating scale, namely: *almost always* = 4, *often* = 3, *sometimes* = 2, or *rarely* = 1. While 16 of the statements denote positive behavior and six of them imply negative behavior (Appendix 1). The Checklist was completed by the Treatment Class only during the first (pre-test) and last (post-test) weeks of the intervention. This is because the philosophy and principle of cooperative learning is in line with the socio-constructivists view of learning which helps the teacher to identify misconceptions and intervene to improve his teaching and facilitate students' learning.

Mean students' responses of the pre-test and post-test of each item/statement were compared using paired sample t-test to assess whether a significant change in student behavior was evident as a result of using small-group cooperative learning model. The instrument was subjected to content validity by some adept personnel in the area of education. A more in-depth study was made by these experts to ensure the representativeness of the items in this questionnaire. The rationale for each item was based on what the instrument was designed to measure.

Procedural-Conceptual Mathematics Test (PCMT). The PCMT is a 30-items test prepared from Math 122 teaching material and classroom activities. Fifteen of the questions were Procedural (scored out of 30 points) and the other 15 were Conceptual (scored out of 30 points). The Conceptual questions were advanced correspondingly from their Procedural counterparts. The Procedural questions require applications of simple procedures, algorithms, and/or rules, whereas, the Conceptual questions require understanding of concepts in mathematics. PCMT was also useful to assess students' ability in identifying, formulating, and solving problems as well as evaluating results. The test was developed by the researchers based on suggestions by several authors (van de Walle, 1998; Cobb, et al., 1991; Koehler and Prior, 1993; Brumbaugh, et al., 1997) (Appendix 2). The test was administered to both classes on their completion of the intervention. Mean scores of the Treatment and Comparison classes were compared using independent sample t-test. Mean scores of the Procedural and Conceptual mathematics tests of each class were also compared using paired sample t-test.

The significant difference ($\rho < 0.001$) between the more able and less able students indicated that the construct validity of the test was assured. Moreover, the split-half reliability test evidenced that the reliability of the whole test was estimated to be higher (0.78) than the correlation between the odd and even scores (0.64).

Math 122 test scores: The sums of the scores of Math 122 mid and final exams, which added up to 50, were the third source of data. Both classes took the tests. Samples are available in Appendix 3. The aim of this test was to triangulate data collection so that the results of analysis on the other data are supported to a larger extent. In all cases, comparisons were made at *a priori* significance level of $p \leq 0.01$.

Results

Group Performance Rating Checklist

Group Performance Rating Checklist was designed to measure the quality of participation within small-group cooperative learning groups. The Checklist contains six students' classroom learning behaviors pertinent to cooperative learning. Pre-test data analyses showed that mean students' responses to positive GPRC statements ranged from 2.05 (SD = 1.01) to 2.63 (SD = 1.01). Likewise, students' responses to negative GPRC statements range from 2.90 (SD = 1.10) to 3.23 (SD = 1.21). These imply that mean students' responses to positive GPRC statements revolved around "sometimes" and "often", while mean students' responses to negative GPRC statements revolved around "often".

Similarly, post-test data analyses revealed that mean students' responses to positive GPRC statements ranged from 3.18 (SD = 0.90) and 3.58 (SD = 0.64). On the other hand, mean students' responses to the negative GPRC statements ranged from 1.33 (SD = 0.76) and 1.95 (SD = 0.96). In this case, mean students' responses to positive GPRC statements was between "often" and "almost always", while mean responses to negative statements ranged between "rarely" and "sometimes". Comparisons of mean pre-test and post-test responses to positive GPRC statements showed that in 15 of the 16 cases, mean post-test responses were significantly greater than mean pre-test responses ($t = -2.70$ to -5.91, $p \leq 0.01$). On the other hand, comparisons of mean pre-test and post-test responses to all negative GPRC statements showed that mean pre-test responses were significantly greater than mean post-test responses ($t = 3.53$ to 6.40; $p \leq 0.01$) (Table 1). These imply that the students in the Treatment Class made significant shifts towards demonstrating learning behaviors that enhance learning in small-group cooperative learning settings while abandoning hindering behaviors.

Table 1: Mean (SD) Students' Responses to GPRC Statements

Student Behaviors and Statements		Mean (SD) Students' Responses		t-Test	
		Pre-test (n = 40)	Post-test (n = 40)	t	*P*
Participation	1*	3.23 (1.21)	1.33 (0.76)	6.40	.000
	2	2.20 (1.16)	3.48 (0.68)	-4.60	.000
	3*	2.90 (1.30)	1.60 (0.90)	3.91	.000
	4	2.30 (1.02)	3.45 (0.75)	-4.35	.000
Staying on-task	1	2.35 (1.12)	3.58 (0.55)	-4.77	.000
	2	2.05 (1.01)	3.50 (0.60)	-5.91	.000
	3*	2.90 (1.10)	1.78 (0.80)	3.83	.000
	4	2.40 (1.15)	3.38 (0.81)	-3.32	.002
Supporting	1	2.58 (1.28)	3.58 (0.64)	-3.49	.001
	2	2.23 (1.10)	3.33 (0.66)	-4.11	.000
	3*	3.08 (1.10)	1.95 (0.96)	3.53	.001
Consideration	1	2.20 (1.16)	3.38 (0.74)	-4.01	.000
	2	2.05 (1.01)	3.33 (0.66)	-5.09	.000
	3*	3.10 (1.22)	1.80 (0.88)	4.03	.000
	4	2.08 (0.97)	3.25 (0.81)	-4.31	.000
Involving Others	1	2.35 (1.14)	3.38 (0.74)	-3.51	.001
	2	2.35 (1.08)	3.18 (0.90)	-2.74	.009
	3	2.35 (1.17)	3.20 (0.88)	-2.70	.010
Communicating	1	2.58 (1.15)	3.30 (0.79)	-2.47	.018
	2	2.53 (1.09)	3.35 (0.86)	-2.80	.008
	3	2.63 (1.01)	3.40 (0.71)	-3.02	.004
	4*	2.90 (1.10)	1.70 (0.94)	3.81	.000

*NB: * Negative student behavior statements; df = 39; p = 2-tailed.*

Procedural-Conceptual Mathematical Test

Cooperative learning settings elicit student behaviors that support thoughtful activities leading to conceptual learning. Therefore, this study predicted that small-group cooperative learning would promote conceptual learning. For this purpose, the PCMT was given to both the Treatment and Comparison classes up on their completion of the intervention. Mean Procedural, Conceptual, and Total test scores of both classes were compared using independent sample t-test. Mean Conceptual test score of the Treatment

Class (18.60, SD = 5.32) was significantly greater than that of the Comparison Class (13.89, SD = 5.68) ($t = 3.73$, $p \leq 0.01$). Likewise, mean Total test score of the Treatment Class (40.40, SD = 9.42) was significantly greater than that of the Comparison Class (33.44, SD = 11.61) ($t = 2.88$, $p \leq 0.01$). Nonetheless, no significant difference was observed between mean Procedural test scores of the two classes (Table 2). Mean Procedural test scores of both classes were significantly greater than that of Conceptual test (Table 3).

Table 2: Performances of Treatment and Comparison Classes

Variables	Mean (SD) scores		t-test	
	Treatment (n = 40)	Comparison (n = 36)	t	*P*
PCMT Procedural test (30 pts)	21.90 (4.94)	19.83 (6.70)	1.54	.128
PCMT Conceptual test (30 pts)	18.60 (5.32)	13.89 (5.68)	3.73	.000
PCMT Total (60 pts)	40.40 (9.42)	33.44 (11.61)	2.88	.005
Math 122 test (50 pts)	35.51 (9.75)	26.24 (11.18)	3.86	.000
College CGPA (4 pts)	2.80 (0.48)	2.72 (0.53)	0.75	.452

NB: df = 74; *p* = 2-tailed.

Table 3: Procedural and Conceptual Test Scores

Classes	Mean (SD) test scores		t-test		
	Procedural test	Conceptual test	df	t	*p*
Treatment (n = 40)	21.90 (4.94)	18.60 (5.32)	39	5.27	.000
Comparison (n = 36)	19.83 (6.70)	13.89 (5.68)	35	8.26	.000

NB: *p* = 2-tailed.

Basic Mathematics II (Math 122) Test

The second important purpose of the study was to look into the contribution of cooperative learning setting in students' mathematics achievement. Mean Math 122 scores of the Treatment and the Comparison classes were compared using independent sample t-test. The analysis showed that mean Math 122 score of the Treatment Class (35.51, SD = 9.75) was significantly greater than that of the Comparison Class (26.24, SD = 11.18) at $p \leq 0.01$ (Table 2).

Year I College CGPA

The purpose of using CGPA was to compare the prior academic performance of the two classes. CGPA served as pre-test data for PCMT and Math 122 tests. Analyses of CGPA showed that both classes have comparable prior academic performance ($t = 0.75$; $p \geq 0.01$) (Table 2).

Discussions

In this section, the findings of the study are briefly discussed in relation to each of the questions of the study.

Improving Student Involvement in Learning Mathematics

It is well established that small-group cooperative instructional strategies enhance learning with understanding. Cooperative learning schemes educe students' behaviors that facilitate learning with understanding. The cooperative learning strategy employed in the present study was designed in such a way that six essential student learning behaviors dominate the instructional milieu. These were: (a) participation of group members, (b) persistence, i.e. staying on-task, (c) supporting group members through offering useful idea, (d) consideration, i.e. valuing peer's contributions and providing constructive criticisms, (e) involving others during group activities, and (f) communicating with peers and the teacher fluently, expressing their ideas clearly and effectively.

Analyses of GPRC data showed that before the commencement of the intervention, the students acknowledged that they would demonstrate many of the classroom behaviors that facilitate learning less often. By the completion of the intervention, the frequently in which positive classroom learning behaviors were demonstrated ranged from often to always. On the other hand, although students responded in pre-test that they would demonstrate behaviors that obstruct learning in groups, such behaviors became quite less apparent by the end of the intervention. Evidently, the intervention enabled students to make significant shifts towards routinely demonstrating learning behaviors that enhance learning in cooperative learning setting while abandoning those that slow learning. Such shifts helped students develop perseverance to solve perplexing problems and motivate them to learn mathematics. Several studies reported similar findings (e.g. Fitzgerald and Bouck, 1993; Hopkins, 2002; Huetinck and Munshin, 2000; Marsh, 2004; McGlinn, 1991; NCTM, 2000; Posamentier and Stepelman, 1996; Slavin, 1987). A number of well-known projects reported the contribution of small-group cooperative learning in motivating students to learn mathematics. These include: (a) the Cognitively Guided Instruction (CGI) based project called "Increasing the Mathematical Power of All Children and Teachers (IMPACT)" (Carey, et al., 1995), (b) the "Qualitative Understanding: Amplifying Student Achievement and Reasoning (QUASAR)" (Silver, et al., 1995), and (c) the "San Diego Mathematics Enrichment Project (SDMED)" (Bezuk, et al., 1993). Also, a study by Good and coworkers among elementary and middle grade students revealed that small-group cooperative instruction enhanced students' social and communication skills (Good, et al., 1989-90).

Enhancing Student Ability to Solve Conceptual Mathematics Problems

The basic principle of mathematics instruction strives to create a learning environment that helps students develop the ability to construct understanding and evaluate ideas, rather than passively accept information. The purpose of using small-group cooperative learning strategy, in this study, was to facilitate conceptual mathematics learning. We have shown above that the cooperative learning strategy was employed satisfactorily as students made significant shifts towards demonstrating supportive learning behaviors. Students were actively engaged in the instructional processes through practicing learning behaviors that foster conceptual understanding.

The Procedural-Conceptual Math Test included two parts, namely Procedural and Conceptual tests. Analyses of PCMT scores revealed that the Treatment Class outperformed the Comparison Class in the Conceptual test. Despite no statistically significant difference was evident in the Procedural test, the Treatment Class outperformed its counterpart in mean

Total test score (Table 2). One interesting observation of the PCMT data is that, in both classes mean Procedural test score is statistically significantly greater than mean Conceptual test score. The difference between mean Procedural and Conceptual test scores of the Comparison Class was about twice that of the Treatment Class (Table 3). The present study revealed that cooperative learning settings that led to various learning activities enhance conceptual learning significantly. A study by Cobb, et al. (1991) reported that students working in small-groups during problem-centered mathematics instruction outperformed non-treatment counterparts on measures of conceptual understanding and higher order applications. In fact, van de Walle (1998) argued that the discourses and interactions in small-group cooperative learning promote higher order thinking, which would lead to conceptual understanding. Likewise, Phelps and Damon (1989) asserted that small-group cooperative learning enhance conceptual understanding rather than rote learning.

Improving Student Performance in Mathematics

As revealed in their CGPA both classes had comparable academic performance prior to the intervention (Table 2). The pre-intervention training in small-group cooperative learning and its use throughout the semester enabled the Treatment Class to outperform the Comparison Class in mean Math 122 test score. The Comparison Class was taught using traditional teacher-dominated model that provides students with very little opportunity to actively participate in the instructional process. The small-group cooperative learning strategy enabled students to exert utmost efforts and employ all their resources to achieve better in the course. Previous authors reported similar findings. For example Jardine and McDuffie (2001) investigated the contribution of cooperative learning and mathematics among fifth grade students and came up with similar finding. Also, Slavin (1988) and McGlinn (1991) reported a profound contribution of cooperative learning in promoting students mathematical problem solving abilities, thus boosting achievement. Furthermore, a study by Qin, Johnson, and Johnson (1995) revealed that members of cooperative learning teams consistently outperformed competing individual learners. Yackel, et al. (1990) studied the effects of small-group cooperative learning among second graders and found out that students in treatment classes outperformed those in comparison classes in mandated tests.

Implications for Classroom Practices and Research

The study demonstrated that heterogeneous small-group cooperative learning strategy boosts students' ability to contribute their share in learning mathematics. It enables them to develop the sense of responsibility, leadership, and managerial skills in the process of learning. Moreover, it opens door for greater interaction through which negotiation of meanings and sharing of ideas are enhanced. Thus, classroom teachers and teacher educators should explore and employ innovative instructional strategies, such as small-group cooperative learning strategy, that enable students become accountable and responsible for their learning.

Likewise, the study showed that small-group cooperative learning motivates students to learn mathematics and develop perseverance to tackle challenging problems. One student in the Treatment Class provided the following reflection on the benefits of heterogeneous small-group cooperative learning:

> The wider gap in ability among us [the students] at the beginning of semester is greatly narrowed as the result of the intervention using cooperative learning strategy. We [the students] all as a class are converged into comparable, enhanced ability in mathematics. Even though we were hesitant and unwilling to work cooperatively at the beginning, we are now impressed with the contribution of cooperative learning. We have learned how to solve problems cooperatively that could require an individual to spend much of her/his time, or that are difficult to attempt. We attempted to solve problems using different strategies. We negotiate meanings, strategies, and tools to solve problems.

The success of small-group cooperative learning lessons depends on good planning, effective implementation, and careful monitoring of its execution. The teacher or teacher educator should: understand the principles of small-group cooperative learning, be capable of eliciting appropriate learner behavior in every phase of small-group cooperative learning, and have a repertoire of models of cooperative learning from which s/he can make choices according to prevailing instructional context. Thus, teachers and teacher educators should be acquainted with principles, models, phases, and tips of cooperative strategies to run effective instruction that result in meaningful mathematics learning.

Effective instruction of a small-group cooperative lesson depends on students' ability to participate productively. For this purpose, students should be acquainted with the methods and strategies of learning in that particular setting. Thus, the implementation of small-group cooperative learning strategy, or any other new strategy for that matter, should proceed with training of the students in the use of the instructional strategy.

This small-scale classroom research has explored into the contributions of small-group cooperative learning in promoting students involvement in learning, enhancing their conceptual understanding, and boosting their mathematics achievement. It could be considered as a springboard for a broader research project in small-group cooperative instructional strategy across levels and subject areas. A wider research project involving more participants and researchers is recommended to consolidate the results.

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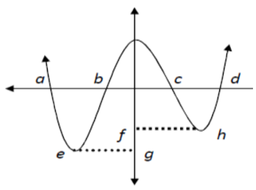
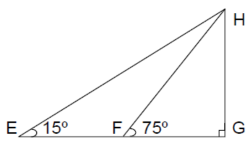
Appendices

Appendix 1: Group Performance Rating Checklist

Student Behavior	Statements	Rating **			
		4	3	2	1
Participation	1. You participate in group discussion without promoting others. *				
	2. You do your fair share of the work.				
	3. You dominate the group, interrupt others, and speak too much. *				
	4. You participate in group activities.				
Staying on-task	1. You listen carefully, pay attention to what is being said & done.				
	2. You make comments to bring the group back to the topic.				
	3. You get off the topic; change the subject. *				
	4. You stay on the topic, the task.				
Supporting	1. You give ideas and suggestions that help the group.				
	2. You offer heedful criticism and comments.				
	3. You influence group decisions and plans. *				
Consideration	1. You make positive and encouraging remarks about group members and their ideas.				
	2. You give recognition and credit to others for their ideas.				
	3. You make inconsiderate, hostile comments about a group member. *				
	4. You are considerate of others.				
Involving Others	1. You involve others by asking questions, requesting inputs, or challenging them.				
	2. You invite group members to work together to reach agreements.				
	3. You consider the ideas of others seriously.				
Communicating	1. You speak clearly that is audible, and comprehendible.				
	2. You express ideas clearly and effectively.				
	3. You listen to and read directions, and respond to teacher and classmates' queries.				
	4. You speak to somebody not on-task, doodle, stare at others, look through the window, make noises, and walk around. *				

* Negative student behavior statements; ** 4 = almost always, 3 = often, 2 = sometimes, 1 = rarely.

Appendix 2: Procedural-Conceptual Mathematics Test

Procedural Test Questions	**Conceptual Test Questions**
1. Find the roots of: $P(x) = x^3 – 2x^2 – x + 2$	1. What is wrong with the following statement? “If a graph of a polynomial function crosses the x-axis three times, then it’s necessarily degree three.” Justify your response.
2. Suppose $P(x) = x^3 – x – 1$. Does $P(x)$ have a solution between 0 and 1? 3. Find the vertical asymptote of the rational function $R(x) = [3x + 1] / [x^2 – 4]$	2. If $P(x)$ is a polynomial function, and a and b are real numbers such that one of the numbers $P(a)$ and $P(b)$ is positive and the other is negative, there is a one zero of P between a and b. (a) Restate this theorem in your own words; (b) Use diagram to show the condition and relate it with factor theorem.
4. Determine the number of times the graph of the polynomial function $P(x) = x^3 – \pi x^2 – x + \pi$ <u>crosses the x-axis</u>. 5. Find the volume of a right circular cylinder with base radius 4cm and height 3cm.	3. Can the graph of a rational function cross its vertical asymptote? Why or why not? 4. Interpret the graph of a polynomial to the right. 
6. If the sine of angle A is 0.5, in a right triangle ABC find the lengths of the legs, a and b, if the hypotenuse, c = 10 cm.	5. A circle may be considered a “many-sided” polygon. Use this notion and: (a) describe the relationship b/n a prism and a cylinder, and (b) develop the volume of a cylinder.
7. If for acute angle θ, $\cos\theta = 4/5$, then find $\sin\theta$.	6. If $\cos\theta = 4/5$ in right triangle, does it necessarily mean one leg is 4 units and the hypotenuse 5 units? Justify your answer and support it with a diagram.
8. Find h = HG in the figure to the right, if EF = 4 units long.  9. Solve $\log_2 x(x – 4) = 5$. 10. Evaluate $\log_8 64$.	7. An angle of a right triangle has a cosine of 0.9375. Which is longer, the leg adjacent to the angle or the leg opposite to the angle? Justify your answer. 8. Three points A, B, and C lie in a straight line on a level ground. A tower CD whose foot is at C is such that the angles of elevation of D from A and B are 30º and 45º respectively. If

11. Sketch the graphs of
$y = 2^x$ and $y = (½)^x$

12. Are the lines l_1: $2x + 4y + 5 = 0$ and
l_2: $3x + 6y – 4 = 0$ are parallel?
13. A line makes an angle of 30º with the positive x-axis. Find the line's slope.
14. A solid metal in the form of a right circular cylinder has radius of 6cm and height 12cm. How big is its volume?
15. Solve the following system of equations:

$$\begin{cases} 3x + 2y = 9 \\ 2x + y = 4 \end{cases}$$

the distance AB is 400m find the height CD of the hill. Use diagram to solve the problem.
9. What is wrong with the statement "the logarithm of the product of two numbers is the sum of the logarithms"? Justify your answer!
10. Does $log_1 6$ make sense? Why or why not?
11. Use the concept on the graph of $y = 2^x$ to sketch the graph of $y = – 2^x$. Elaborate how these two functions are similar & different! Give as many statements as you can.
12. Explain in more than one way why two lines with the same slope are parallel.
13. Explain how you might find a measure of an angle of a staircase that will describe the staircase's steepness.
14. A solid metal cylinder with radius 6cm & height 18cm is melted down. The entire volume of metal is then used to make a cone with a radius of 9cm. How tall will the cone?
15. Find A and B if $A(3x + 2) + B(2x + 1) = 9x + 4$.

Appendix 3: Sample Questions of Math 122 Mid-test and Final Exam

Mid Test 5 Items, Multiple Choice; 5 Items : Short Answers; 1 Item: Workout; Time Allotted: 2:00 Hrs

Sample 1
Which of the following is not a polynomial?
A. $(3x^4 + 5) \div 4$
B. $(x^8 + 2) \div [x^8 + 2]$
C. $[(x^4 + 1)^2]^{1/2}$
D. $(x^2 – 1) \div (x – 1)$
E. None of the above

Sample 2
The solution set of $[(x^2 + 2x) \div (x^2 + 1)] \geq 0$ is ____.

Sample 3
Let $p(x) = x^3 + bx + c$ be a polynomial. If the remainder is 2 when $p(x)$ is divided by $x+2$ and $x-1$ is a factor of $p(x)$, then find the values of b and c. Show all the necessary steps neatly and clearly.

Final Exam 5 Items: Multiple Choice; 15 Items: Workout; Time Allotted: 1:30 Hrs.

Sample 1
Identify the <u>false</u> statement.
A. $\sin 15^o \cos 45^o = (3^{1/2} – 1) \div 4$
B. $\sin 22.5^o \cos 67.5^o = (2^{1/2}) \div 4$
C. $\sin 105^o + \sin 15^o = (6^{1/2}) \div 2$
D. $\sin 75^o – \sin 15^o = (2^{1/2}) \div 4$
E. $\cos 165^o – \cos 75^o = [–(6^{1/2})] \div 4$

Sample 2
How are the graphs of $y = \log_{(1/2)} -x$ and $y = \log_{(1/2)} x$ related?

Sample 3
Evaluate the expression $[(p\cos\theta + q\sin\theta) \div (p\cos\theta – q\sin\theta)] – 1$ to get a value in terms of p and q where $p\cot\theta = p/q$.